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Early Warning and Crop Condition Assessment

February 1984

EVALUATION OF A NATIVE VEGETATION MASKING TECHNIQUE

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16. Abstract

USDA's Foreign Agricultural Service's (FAS) Foreign Crop Condition Assessment Division (FCCAD) has utilized a crop masking technique based on Ashburn's Vegetative Index (AVI). The joint USDA/NASA/NOAA Early Warning Crop Condition Assessment (EW/CCA) Research Project chose to use this technique in the evaluation of native vegetation as an indicator of crop moisture condition. A mask of the range areas (native vegetation) was generated for each of thirteen Great Plains Landsat MSS sample segments. These masks were compared to the digitized ground truth and accuracies were computed. An analysis of the types of errors indicates a consistency in errors among the segments. The mask represents a simple quick-look technique for evaluating vegetative cover.

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Job Order 72-474

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February 1984

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ACRONYMS

AVI	Ashburn Vegetative Index
CCA	Crop Condition Assessment
DVI	Difference Vegetative Index
FAS	Foreign Agricultural Service
FCCAD	Foreign Crop Condition Assessment Division
GVI	Green Vegetative Index
IAS	Interactive Application System
IMDACS	Integrated Multivariate Data and Analysis Classification System
IR	Infrared
KVI	Kauth Vegetative Index
LACIE	Large Area Crop Inventory Experiment
LAI	Leaf Area Index
MSS	Multispectral Scanner
PFC	Product Film Converter
PVI	Perpendicular Vegetative Index
TVI	Transformed Vegetative Index
UGTT	Universal Ground Truth Tape
USGS	United States Geological Survey
VIs	Vegetative Indices
VIN	Vegetative Index Number

1. INTRODUCTION

1.1 PURPOSE

The purpose of this paper is to document the application and evaluation of a masking technique as a feasible alternative to ground truth information for separating native vegetation* from cropland.

1.2 SCOPE

The scope of this document is primarily concerned with description of the approach which includes the data set, masking technique, and analysis methods and explanation of the results which includes the masking accuracy, error evaluation and time-profile comparisons.

1.3 BACKGROUND

The Early Warning/Crop Condition Assessment (EW/CCA) Research Project, in support of FAS/Crop Condition Assessment Division, is charged with developing and testing remote sensing techniques to make possible or to enhance operational methodologies for crop condition assessment (AgRISTARS Program Management Group).

In response to the overall objective of this project, a task entitled Native Vegetation as an Indicator of Crop Moisture Condition was defined. The masking technique addressed in this report is an integral part of the preceding task. For approximately five years, USDA Foreign Agricultural Service, Foreign Crop Condition Assessment Division, has been utilizing the masking technique in their efforts to produce an estimate of crop condition in foreign areas. The masking technique is a relatively fast method for identifying an area or crop of interest within a LANDSAT MSS scene [Ashburn (1981)]. This technique is especially well adapted for use by the remote sensing analysts in an interactive computer operation situation.

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*Native vegetation is defined as rangelands, pastures, and grasslands in this study of the Great Plains.

2. APPLICATION AND EVALUATION

2.1 APPROACH

2.1.1 RESEARCH DATA SET

The research data set consisting of thirteen 5x6 nautical mile sample segments of Landsat MSS data was selected based on requirements establihsed for the overall task - Native Vegetation as an Indicator of Crop Moisture Condition. The process commenced with a review of over 200 United States Great Plains segments from the Large Area Crop Inventory Experiment (LACIE) data set.

Figure 1 illustrates the details of the data set selection process. Segments were evaluated based on the availability of consecutive years of data and adequate growing season acquisition histories. The final steps included examining aerial photography and plotted maps in order to obtain as much inter-segment diversity as possible in the study area.

A brief description of the research data set is provided in Table 1 and the locations of the selected segments are shown on Figure 2.

The following data products were assembled for each of the thirteen segments included in this task data set:

1. Disk files of the multispectral four channel image data.

2. Production film converter (PFC) Product 1 (color IR composite of MSS bands 4, 5, and 7) for each acquisition.

3. Color infrared photography at an approximate scale of 1:24 000 accompanied by two Gerber plots (digitized field/crop overlay), one scaled to the photography and the other to the Product 1.

4. A disk version of the universal ground truth tape (UGTT) of the digitized ground truth inventory.

Figure 1. – RESEARCH DATA SET SELECTION PROCEDURE

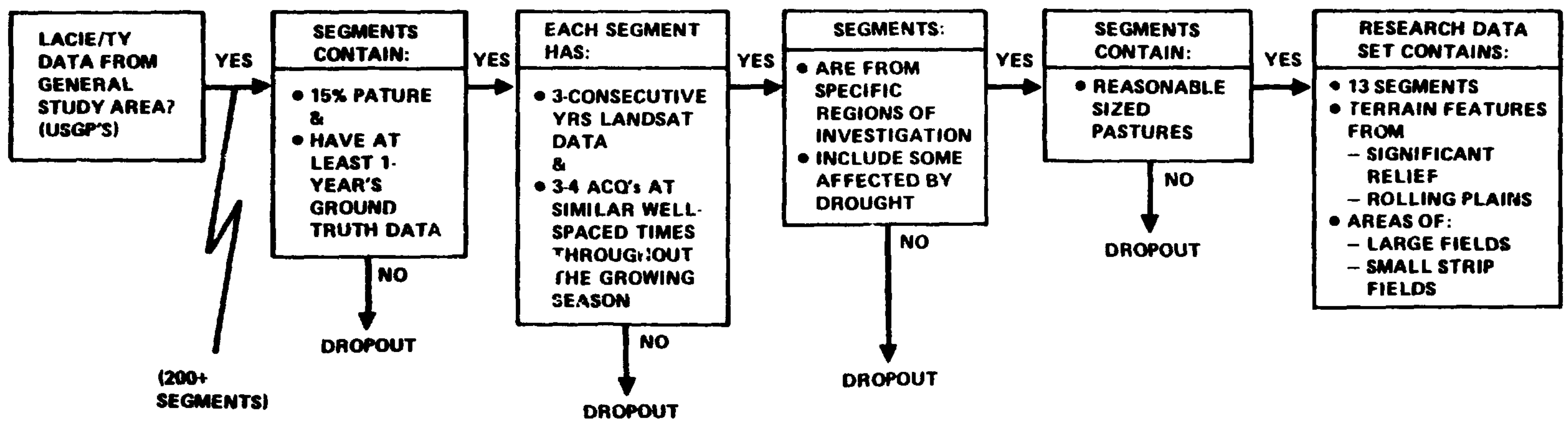

Table 1. - RESEARCH DATA SET DESCRIPTIONS

SEGMENT NUMBER	COUNTY	CRD	STATE	LATITUDE	LONGITUDE	NO. YEARS COVERED	COMMENTS
[illegible]32	WICHITA	40 WC	KS	38°22′	101°21′	4	LARGE PASTURE AREAS; 26% PASTURE; '76 DROUGHT STUDY
1003	ADAMS	60 EC	CO	39°51′	104°08′	4	LARGE PASTURE AREAS; 26% PASTURE
1583	HITCHCOCK	70 SW	NB	40°12	101°04′	4	LARGE PASTURE; ROUGH TERRAIN; 40% PASTURE
1596	THAYER	90 SE	NB	40°12	97°2[illegible]′	4	MED. PASTURE; SOMEWHAT ROLLING TERRAIN; 37% PASTURE
1637	STUTSMAN	50 C	ND	47°15′	99°19′	4	SCATTERED PASTURE; LAKES; 27% PASTURE
1653	BURLEIGH	80 SC	ND	47°01′	100°20′	5	LARGE PASTURE; UNEVEN TERRAIN; 39% PASTURE
1661	McINTOSH	90 SE	ND	46°16′	99°45′	4	LARGE PASTURE AREAS; 41% PASTURE; '76 DROUGHT
1677	SPINK	20 NC	SD	45°04′	98°06′	4	GOOD PASTURE AREAS; 20% PASTURE; '76 DROUGHT
1686	BEADLE	50 C	SD	44°14′	98°25′	4	GOOD PASTURE AREAS; 44% PASTURE; '76 DROUGHT
1694	LYMAN	80 SC	SD	43°51′	100°06′	3	GOOD PASTURE AREAS; ROUGH TERRAIN; 31% PASTURE; '76 DROUGHT
1755	JERAULD	[illegible] C	SD	44°03′	98°53′	3	GOOD PASTURE AREAS; 50% PASTURE; '76 DROUGHT
1059	OCHILTREE	11 NNW	TX	36°15′	100°52′	3	LARGE PASTURE AREAS; 44% PASTURE; '76 DROUGHT
1266	WILBARGER	21	TX	34°03′	99°14′	4	LARGE PASTURE AREAS 6[illegible]% PASTURE

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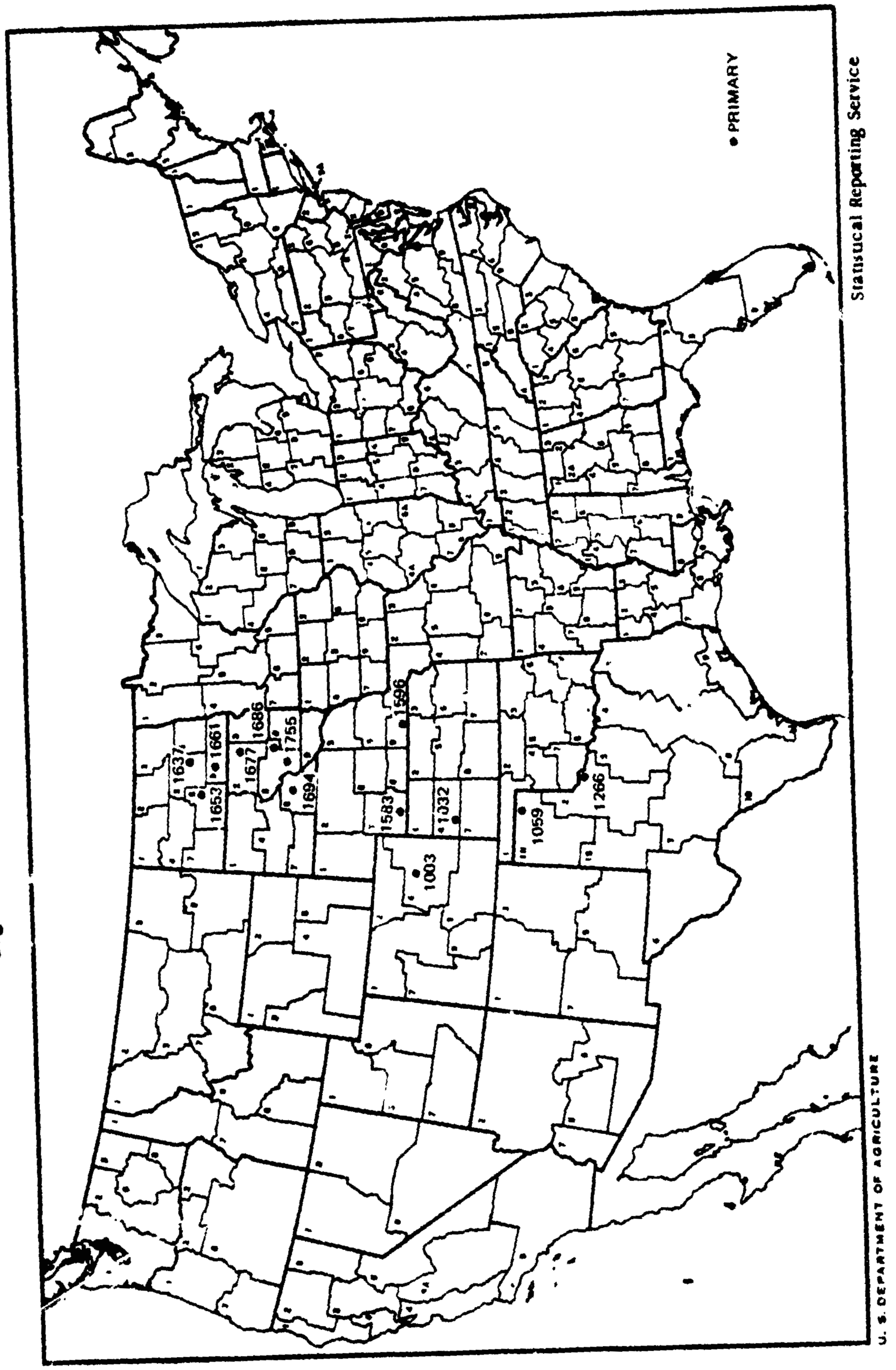

Figure 2. - RESEARCH DATA SET LOCATIONS

5 USGS (United States Geologic Survey) maps at a scale of 1:250 000 with the appropriate segment plotted.

6. Other pertinent ancillary data such as crop statistics, cultivation practices, crop calendars, geographic descriptions, and soils data.

2.1.2 MASKING TECHNIQUE

Masking was accomplished on a DEC PDP 11/70 computer system under the Interactive Application System (IAS) operating system using the Crop Condition Assessment processor (CCA).

The masking technique developed by FAS/FCCAD [Ashburn (1979)] is based on a single MSS acquisition that displays separability between native vegetation and cropland. Also, the assumption has been made that the cropland to native vegetation area ratio as delineated by the mask is static, relatively unchanged from year to year, and therefore, will be applicable for multiple acquisitions and years.

The Ashburn Vegetative Index (2 times Landsat Band 7 minus Band 5) is used in mask creation because it is the primary VI used by FCCAD in operational masking. Aaronson, Davis and May (1979) concluded that the vegetative indices - AVI, DVI, GVI, KVI, LAI, PVI and TVI - were highly correlated. Lautenschlager and Perry (1981) used variable clustering and functional equivalence techniques to arrive at the same conclusions.

The procedure followed in masking native vegetation is listed below:

1. Using crop calendar information to establish native vegetation and cropland separability, select an image acquisition date.

2. Display the selected color IR image acquisition date (Product 1) on the CCA's primary image display screen and transfer the image to the secondary screen.

3. Create a gray scale AVI image of the acquisition on the primary screen.

4. Analyze the color IR image. Visually compare the color IR image and the gray scale AVI image. More than one color IR image may be analyzed in order to establish the area of interest.

5. Using an alarm process available in IMDACS, establish a range of AVI values for the area of interest (native vegetation).

6. Using the AVI values, create a black and white image, a mask, for the area of interest.

2.2 METHODS, RESULTS AND DISCUSSION

2.2.1 MASKING ACCURACY

The accuracies of the masks were determined by comparing each segment mask to the segment digitized ground truth. A mask/ground truth comparison map is shown in Figure 3. Accuracy proportion statistics were computed and output in table format. A summation of these statistics appears in Appendix A.

The ground truth is digitized to the sub-pixel level. There are six ground truth sub-pixels for every Landsat pixel. Accuracy statistics were computed at three levels based on the ground truth sub-pixel. The ground truth label for the all-pixel level, which totals 22,932 pixels, was determined by majority rule or the first pixel encountered basis [McIntyre (1982)]. The pure pixel statistics were computed on those pixels with six of six sub-pixels in crop code agreement. An overview of the data with a breakdown of mask/ground truth agreements to the sub-pixel level was also generated.

The proportion of pixels in agreement ranged from .82 to .68 for all pixels in the scene, .86 to .69 for all pure pixels in the scene, and .83 to .47 for range ground truth pure pixels. Eight of the thirteen segments were undermasked. If the user is interested in pixel for pixel accuracy, the mask, judging from these statistics, is not a feasible alternative.

Therefore, another approach was undertaken to evaluate the mask. In addition to the detailed summary statistics given in Appendix A, three

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Figure 3: Partial Ground Truth/Mask Comparison Map, Segment 1266

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Key:
* - Areas of Agreement
C - Areas of Commission
" - Areas of Partial Disagreement
% - Areas of Partial Agreement
0 - Areas of Omission

different procedures were used to rank the thirteen segments for overall mask quality. These are described below.

1. Professional judgment of mask quality: the analyst, without knowledge of the next two procedures, ranked the segments according to overall mask quality from best to worst. The analyst rankings are listed in column 1 of Table 2.

2. Kendall's tau computed on agreement-disagreement of mask and ground truth: the tau coefficient proposed by Kendall (1948, 1955) is a measure of the extent of agreement between judges (mask and ground truth).

$$\tau = \frac{n_{agree} - n_{disagree}}{\frac{n(n-1)}{2}}$$

$$= \frac{n_{agree}}{\frac{n(n-1)}{2}} - \frac{n_{disagree}}{\frac{n(n-1)}{2}}$$

From the last expression, one sees that tau can be thought of as the proportion of agreements minus the proportion of disagreements between the two rankings. Perfect agreement corresponds to a tau of 1; perfect disagreement corresponds to a tau of -1, Lindeman (1980). The computed tau values for each segment and their respective rankings based on them are given in columns 2 and 3 of Table 2.

3. Fisher ranking information: this method provides a "measure" of the relative amount of information in the mask labels versus the ground truth labels which is available for estimating the range proportion "p."

$$S(p,\alpha,\beta) = \left\{1 - \left[\frac{\alpha(1-)}{p\alpha + (1-p)(1-\beta)} + \frac{\beta\ (1-\alpha)}{p(1-\alpha) + (1-p)\beta}\right]\right\}$$

where

p = true proportion of range,

α = probability of masking range as range, and

β = probability of masking non-range as non-range

The quantity $S(p,\alpha,\beta)$ is between zero and one. It provides a measure of the information loss induced by the uncertainty in the mask labels. For example, $S(p,\alpha,\beta) = 0.42$ means on the average there is only 42% as much information in a mask label available for estimating the range proportion "p" as there is in a ground truth label. For a discussion of Fisher information in this context see Perry (1981). The relative Fisher information in the segment masks and the induced rankings are given in columns 4 and 5 of Table 2.

By comparing columns 1, 3, and 5 of Table 2, one observes that there is substantial agreement about mask quality as judged by the three procedures. The analyst professional judgment agrees with the tau ranking except for one inversion (the ordering of segments 1059 and 1596). There is less agreement between the analyst-Fisher and Fisher-tau rankings, but even in these pairs, the basic ordering is generally the same. Our subjective evaluation that the three procedures are similar is confirmed by treating each of three ranking systems as judges and computing Kendall's tau coefficient for each pair of rankings. The total number of agreements, tau, and the significance level for tau is given for each pair in Table 3. From the sample statistics one concludes that the ranking of the mask quality in each pair are significantly related. Given the tau and

Table 2. - Masking Accuracy Analysis by Segment

ANALYST RANKING	TAU VALUES	KENDALL'S TAU RANKING	FISHER'S INFORMATION MEASURE	FISHER'S RANKING
1637	.666	1637	.4206	1266
1266	.643	1266	.3458	1583
1003	.605	1003	.3201	1637
1032	.595	1032	.2964	1032
1583	.589	1583	.2653	1003
1677	.529	1677	.2432	1686
1694	.517	1694	.2431	1694
1686	.495	1686	.2036	1653
1653	.449	1653	.1738	1677
1059	.400	1059	.1505	1059
1596	.362	1755	.1329	1755
1755	.359	1596	.1255	1661
1661	.345	1661	.0807	1596

Table 3. - Results of Using Kendall's Tau as a Measure of the Relationship Between Pairs of Variables in the Form of Ranks

	TOTAL AGREEMENTS BETWEEN RANKINGS	KENDALL'S TAU	STATISTICAL SIGNIFICANCE OF TAU
ANALYST/TAU	77	.970	.0001
ANALYST/FISHER	69	.769	.0002 or better
TAU/FISHER	70	.795	.0002 or better

significance level associated with the analyst-tau ranking systems (0.97 and 0.0001), it would appear that the information the analyst is subjectively considering when judging mask quality is the same information numerically captured by the tau ranking procedure. If this is in fact true, one concludes that the analyst's rankings are primarily based on the agreement-disagreement of mask versus ground truth as this is the only information used in computing the tau value for a segment mask.

2.2.2 ERROR EVALUATION

The causes or types of masking errors were evaluated by an analyst using the mask acquisition date PFC Product 1, the aerial photography, both Gerber plots, gray-scale ground truth map, the mask/ground truth comparison maps and other Product 1 acquisition dates necessary for image analysis. Types of errors were categorized, analyzed, and tabulated. Proportions were computed for each category based on the total number of disagreements between the ground truth and the mask for pure pixels. Table 4 summarizes the proportions of errors in each category.

In considering the errors of omission (ground truth range not masked as range), the greatest proportion of the error was in the sparse vegetation (low density) category followed by the lush vegetation category. The AVI values for the pixels in these two categories fell outside the selected range of AVI values for the range masks. In many cases, areas of ground truth range were not vegetated and AVI processing as designed did not include them in the mask. Lush vegetation occurred along drainage ways and in improved grasslands. Including these areas in the mask would have increased the commission error (ground truth non-range masked as range) since increasing the AVI value range would have masked other non-range areas as well.

Fields with weeds or emerging vegetation were generally masked as range and were a leading cause of errors of commission. Senescent vegetation, (turning vegetation with low greenness) presented a confusion problem in four winter wheat segments-1059, 1583, 1596, and 1755. Alfalfa and hay were confusion crops that were masked as range in segements 1661, 1686, 1694, and 1755. Field boundaries where grass grows along a fence

TABLE 4. MASKING ERROR EVALUATION PROPORTIONS

CAUSE	SEGMENTS												
	1003	1032	1059	1266	1583	1596	1637	1653	1661	1677	1686	1694	1755
Field Boundary-Mixed Pixel	.012	.087	.034	.040	.037	.048	.058	.015	.028	.028	.067	.080	.017
Sparse Vegetation (Omission)	.292	.204	.592	.678	.203	.305	.510	.509	.224	.300	.285	.314	.429
Sparse Vegetation (Commission)	.126				.020	.001	.009	.017	.002	.065		.023	
Non-Ag, Homestead, Trees	.028			.025	.132	.026	.040	.157		.033	.004	.004	.018
Weedy Fields, Emerging Vegetation	.314	.514	.028	.115	.154	.087	.283	.134	.317	.225	.213	.377	.110
Unidentified, Undefined Areas (includes cloud shadowed area)	.005	.121	.032	.022	.036	.057		.016					.008
Lush Vegetation	.124	.035	.031	.053	.185	.276	.005	.077	.089	.121	.154	.016	.080
Ground Truth Question, Misregistration	.001		.013	.061	.063	.020	.005	.005	.037	.058	.010		.053
Abandoned Fields		.037	.003	.006									
Pasture Mix (trees)	.083												
Senescent Vegetation			.262		.153	.166							.004
River Bottom, Shoreline	.010				.002	.014							
Strip Fields								.065	.193	.020		.017	.012
Alfalfa and Hay Confusion									.104		.193	.163	.264
Water, Low Areas, Wet Areas, Potholes							.085			.141	.063		
Unaccounted	.005	.002	.005		.015		.005	.005	.006	.009	.011	.006	.005

line were also masked as range, but were considered errors of commission. The mask in this case was performing accurately and as expected.

These examples of error-type define the central cause of masking inadequacy for absolute classification: no vegetation-type can be expected to possess a unique VIN range. Quantative interpretation of LANDSAT MSS data has been checked by variations, both within scenes over time and between scenes. These variations may be produced by atmospheric processes as referenced by Cate (February 1980) or by physical parameters such as moisture content, row direction, soil background, shadows, and wind as summarized in a literature review by Cate (January 1980). On most of the segments, the analyst questioned some of the ground truth inventory or the ground truth registration. Many of the segments had areas that were unidentified or undefined which may have been correctly masked range but due to the ground truth inadequacies were considered in error.

Evaluation of the types of errors leads to the assumption that the masking technique performed relatively well. The ground truth represents a definite yes/no situation, but it is evident that the actual situation is less decisive. The mask perhaps produces a more accurate "picture" of what is "actually" in the ground truth inventory.

2.2.3 PROFILE COMPARISON

Another method of comparing the mask and the ground truth is plotting by segment the computed AVI mean values for the mask and the ground truth for all acquisitions for a year versus time.

Segment 1755, Jerauld County, South Dakota, statistically had one of the lowest proportions of mask/ground truth agreement, and segment 1003, Adams County, Colorado, had one of the highest proportions of mask/ground truth agreement. The range mask and range ground truth AVIs for both segments show little difference in their respective profiles or values (see Figures 4 and 5). This is true of all segments and years.

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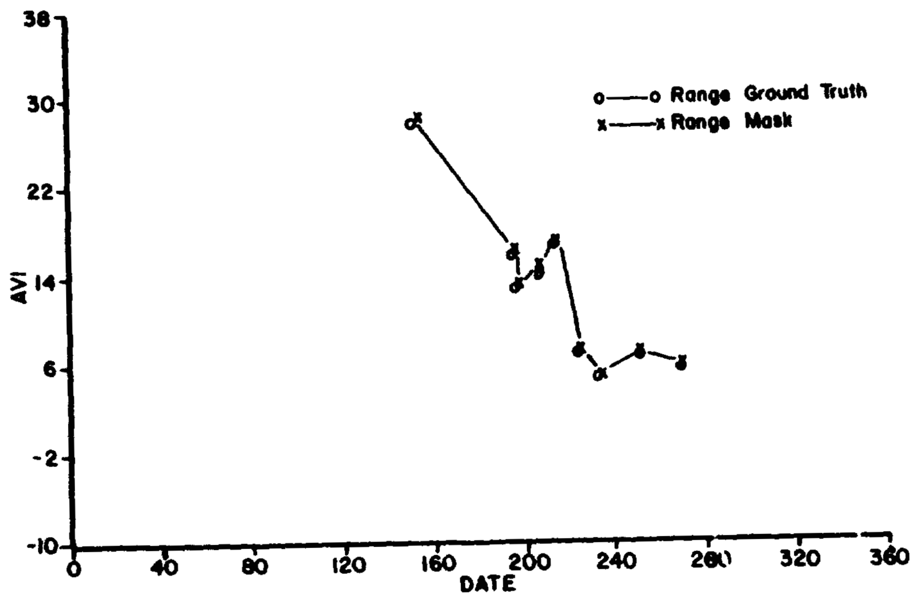

Figure 4. - AVI vs. TIME PLOT FOR RANGE MASK AND RANGE GROUND TRUTH VALUES FOR SEGMENT 1755, JERAULD COUNTY, SOUTH DAKOTA IN 1978.

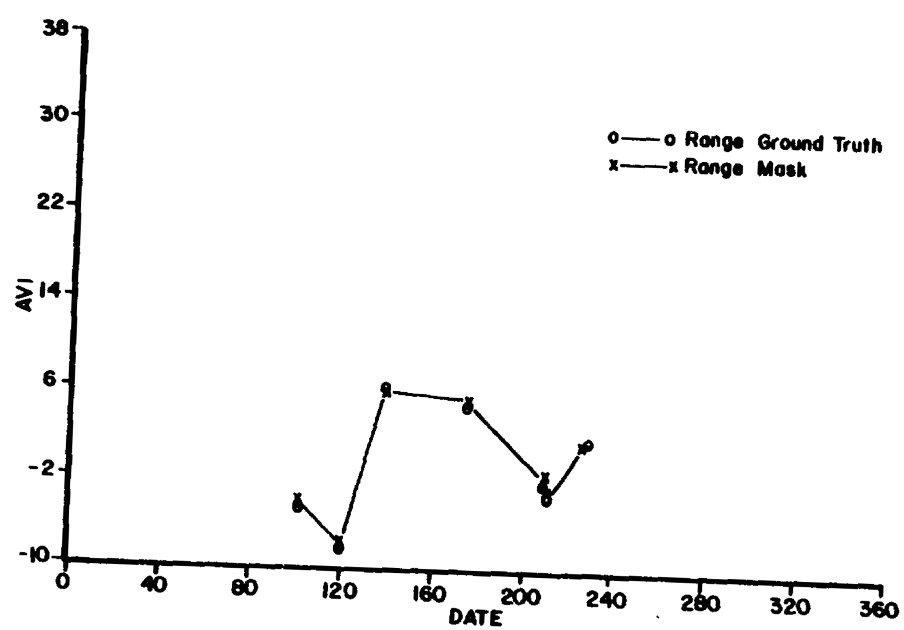

Figure 5. - AVI vs. TIME PLOT FOR RANGE MASK AND RANGE GROUND TRUTH VALUES FOR SEGMENT 1003, ADAMS COUNTY, COLORADO IN 1978.

3.0 SUMMARY

Masking is a successful technique for the user interested in a quick-look procedure expandable to large areas and sufficiently accurate for most operative requirements. This is a simple interactive technique. The acquisition used for masking is critical as the area to be masked must be spectrally separable from the other areas. The types and causes of errors are consistent among segments when analyzing large amounts of data. The AVI vs. time profiles comparisons illustrate that the errors encountered are not a hinderance to the utility of the masking technique.

REFERENCES

Aaronson, Andrew C.; Davis, Larry L.; and May, George A.: Results of the Vegetation Index Correlation Study. Technical Memorandum 6, Crop Condition Assessment Division, FAS/USDA, February 1979.

AgRISTARS Program Management Group: AgRISTARS, Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing, Research Report, Fiscal Year 1982. NASA, Johnson Space Center, AP-J2-0393, January 1983.

Ashburn, Pat: The Vegetative Index Number and Crop Identification, The LACIE Symposium, Proceedings of Technical Sessions, Vol. II, NASA, Johnson Space Center, JSC-16015, July 1979, page 843.

Ashburn, P.: Utilization of the Vegetative Index Number in the US..., Technical Memorandum 11, The Crop Condition Assessment Division, FAS/USDA, May 1981.

Cate, R. B.; Artley, J.A.; and Phinney, D.E.: Quantative Estimation of Plant Characteristics Using Spectral Measurement: A Survey of the Literature. NASA, Johnson Space Center, Technical Report JSC-16298, SR-L0-00408, January, 1980.

Cate, R. B.; Phinney, D. E.; Kinsler, M.C.; Sestak, M. L.; Hodges, T; and Dishler, J. J.: Interpretation of Landsat Digital Data Using A Cubic Color Model Based on Relative Energies. NASA, Johnson Space Center, Technical Report, JSC-13776, SR-L0-00418, February, 1980.

Lautenschlager, Lyle F. and Perry, Charles R., Jr.: Comparison of Vegetation Indices Based on Satellite Acquired Spectral Data. Proceedings of the Survey Research Methods Section of the American Statistical Association, 1981, pp. 72-82.

Lindeman, Richard H.; Merenda, Peter F., and Golch, Ruth Z.: Introduction to Bivariate and Multivariate Analysis. Dallas, Texas: Scott, Foresman and Company, 1980.

McIntyre, K.S. and Miller, T.G. : Pasture/Range Condition Assessment Processor User's Manual, NASA, Johnson Space Center, EW-L2-00754, JSC-18567, 1982.

McIntyre, K.S. and Miller, T.G.: Computer Program Documentation for the Pasture/Range Condition Assessment Processor. NASA, Johnson Space Center, EW-L2-04340, JSC-18265, July 1982

Perry, Charles R. Jr.: A Summary of Observations Concerning the Information in the Spectral-Temporal-Ancillary Data Available for Estimating Ground Cover Crop Proportions. NASA, Johnson Space Center, FC-J0-00486, JSC-16815, February 1981.

APPENDIX A

Summary of Mask/Ground Truth Accuracy Statistics

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TABLE A-1. TOTAL PIXELS BY CATEGORY

Segment Number	All Pixels (GT/MASK)				Pure Pixels (GT/Mask)				Overview Pixels (GT/Mask)									
	RR	RN	NR	NN	RR	RN	NR	NN	RR 5/6	RN 5/6	RR 4/6	RN 4/6	RR 3/6	RN 3/6	RR 2/6	RN 2/6	RR 1/6	RN 1/6
1003	4224	2016	2510	14182	3946	1637	2282	13722	91	138	123	153	118	166	101	223	73	159
1032	4700	1184	3457	13591	4458	1020	3245	13320	71	58	132	79	83	59	112	145	56	94
1059	5875	4369	2507	10181	5660	4115	2300	9823	63	59	101	131	96	123	118	192	44	107
1266	10816	2990	1106	8020	10406	2573	690	7223	203	152	159	184	113	179	220	351	131	348
- 1583	8136	2017	2689	10090	7273	1482	2045	9438	317	177	410	252	273	214	297	296	210	248
1596	3807	4734	2613	11778	3330	3819	2230	10812	184	313	202	422	177	356	177	431	120	359
1637	3956	2344	1487	15145	3626	1762	1189	14003	121	176	152	267	106	270	169	619	80	392
1653	7955	3664	2653	8660	7468	3155	2222	8108	171	180	227	235	183	194	192	249	145	203
1661	6800	2618	4895	8619	6078	2253	4163	8127	224	99	377	209	254	126	425	301	174	122
1677	3616	3380	2017	13919	3243	2711	1691	13045	119	190	189	338	122	274	180	445	89	296
1686	7849	2934	2851	9298	6952	2351	2097	8391	303	208	443	266	321	238	391	472	193	306
1694	5836	1969	3567	11560	5401	1637	3188	11001	150	89	206	170	151	140	192	311	115	181
1755	7965	4107	3204	7656	7438	3493	2678	6862	177	199	265	299	176	238	241	381	194	291

Key

GT - Ground Truth
R - Range
N - Non-Range

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TABLE A-2. PROPORTION STATISTICS FOR ALL PIXELS

SEGMENTS	All Pixels							Proportion	Scene	Mask Acquisition Date
	Proportion of Pixels						Difference in GT/Mask Range Masked	G.T. Labeled Range	Mask Labeled Range	
	Agree	Disagree	Committed	Omitted	Non-Range Committed	Range Omitted				
1003	.8026	.1974	.1095	.0879	.1504	.3231	-0.0215	.2721	.2937	78136 May 18
1032	.7976	.2024	.1508	.0516	.2028	.2012	-0.0991	.2566	.3557	78093 April 3
1059	.7002	.2998	.1093	.1905	.1976	.4265	0.0812	.4467	.3655	77157 June 6
1266	.8214	.1786	.0482	.1304	.1212	.2166	0.0822	.6020	.5199	75166 June 15
1583	.7948	.2052	.1173	.0880	.2104	.1987	-0.0293	.4427	.4720	75187 July 6
1596	.6796	.3204	.1139	.2064	.1816	.5543	0.0925	.3724	.2800	76162 June 10
1637	.8329	.1671	.0648	.1022	.0894	.3721	0.0374	.2747	.2374	78136 May 16
1653	.7245	.2755	.1157	.1598	.2345	.3153	0.0441	.5067	.4626	75171 June 20
1661	.6724	.3276	.2135	.1142	.3622	.2780	-0.0993	.4107	.5100	76129 May 8
1677	.7647	.2353	.0880	.1474	.1266	.4831	0.0594	.3051	.2456	78135 May 15
1686	.7477	.2523	.1243	.1279	.2347	.2721	0.0036	.4702	.4666	78135 May 15
1694	.7586	.2414	.1555	.0859	.2358	.2523	-0.0697	.3404	.4100	76128 May 7
1755	.6812	.3188	.1397	.1791	.2950	.3402	0.0394	.5264	.4870	78135 May 15

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TABLE A-3. PROPORTION STATISTICS FOR PURE PIXELS AND SUBPIXEL LEVEL

SEGMENTS	Pure Pixels							Overview (Subpixel Level)		
	Proportion of Pixels						Proportion of Range Correctly Masked	Proportion		
	Agree	Disagree	Committed	Omitted	Non-Range Committed	Range Omitted		Agree	Disagree	Partial Agreement
1003	.8185	.1815	.1057	.0758	.1426	.2932	.7068	.7705	.1709	.0587
1032	.8065	.1935	.1472	.0463	.1959	.1862	.8138	.7752	.1860	.0388
1059	.7071	.2929	.1050	.1879	.1897	.4210	.5790	.6752	.2797	.0451
1266	.8438	.1562	.0330	.1232	.0872	.1982	.8018	.7688	.1423	.0890
1583	.8257	.1743	.1010	.0732	.1781	.1693	.8307	.7287	.1538	.1175
1596	.7004	.2996	.1104	.1891	.1710	.5342	.4658	.6167	.2638	.1195
1637	.8566	.1434	.0578	.0856	.0783	.3270	.6730	.7688	.1287	.1026
1653	.7434	.2566	.1060	.1506	.2151	.2970	.7030	.6792	.2345	.0863
1661	.6889	.3111	.2019	.1093	.3387	.2704	.7296	.6194	.2798	.1008
1677	.7872	.2128	.0817	.1310	.1148	.4553	.5447	.7103	.1920	.0978
1686	.7753	.2247	.1060	.1188	.1999	.2527	.7473	.6691	.1940	.1370
1694	.7727	.2273	.1502	.0771	.2247	.2326	.7674	.7152	.2104	.0744
1755	.6985	.3015	.1308	.1706	.2807	.3195	.6805	.6236	.2691	.1073